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Assessment of Different Properties of Lightweight Concrete using Expanded Polystyrene Beads Extracted from Thermocol Wastage

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Abstract

Nepal is facing the problem of thermocol wastage, especially in the damping site nearby the urban areas. The thermocol wastage were crushed by a hammer and the extracted expanded polystyrene (EPS) beads was used as aggregates to produce the lightweight concrete. The content of EPS beads was 0, 20, 30, 40, 50, and 60 % by the total volume. Mechanical properties like density, different strengths, and Young's modulus were experimentally evaluated on ranging percentages of EPS. The 28-day compressive, flexural, splitting tensile strengths and Young's modulus of the control mixture were 59.9 MPa, 5.21 MPa, 4.43 MPa, and 20898 MPa respectively. The decrease on compressive strength was by 62 %, 72 %, 81 %, 88 %, and 93 % respectively for 20 %, 30 %, 40 %, 50 %, and 60 % EPS content respectively. It was 26 %, 41 %, 51 %, 57 %, and 69 % for flexural strength, 46 %, 60 %, 70 %, 80 %, and 88 % for the splitting tensile strength and 45 %, 56 %, 61 %, 70 %, and 77 % for Young's modulus respectively. Drying shrinkage, freezing and thawing, and water absorption tests were conducted to evaluate the durability of EPS concrete. All properties were compared with the auto-cleaved lightweight concrete (ALC). It revealed that the EPS beads extracted from the thermocol wastage can be re-used to produce the structural and non-structural concrete depending on its percentages. It can easily solve the never-decomposing problems of thermocol wastage. Moreover, ALC can be replaced by EPS concrete for the in-fill and partition walls of the buildings.

Keywords: ALC, Durability, EPS beads, EPS concrete, Lightweight concrete, Mechanical properties

1. Introduction:

The lightweight concrete can be defined by its density of less than 1800 kg/m^3. The structural lightweight concrete should have a minimum compressive strength of 17 MPa. The non-structural lightweight concrete may have compressive strength in between 0.7 and 7 MPa. The structural and non-structural lightweight concrete is helpful to lighten the structures [1].

Lightweight concrete can be produced by using porous lightweight aggregates. The lightweight aggregates are of both natural and artificial types. Diatomite, Pumice, scoria, volcanic cinders, tuff, etc. are the natural lightweight aggregates. Among them, all except diatomite are of volcanic origin [2]. Artificial aggregates include expanded clay, shale, slate, diatomaceous shale, perlite, obsidian, vermiculite, blast furnace slag, fly ash, etc. [3].

EPS beads are artificial ultra-lightweight aggregates [4].

EPS has the characteristics of low density, hydrophobic properties, good thermal insulation, low absorption, and low cost. Thus, it is generally used as a packaging material. However, it becomes waste after the completion of the packaging purposes, which has raised serious environmental issues due to its non-decomposing nature [5-6].

The concrete with the use of EPS beads, as aggregate, is termed as EPS concrete. EPS beads can be used to replace the normal aggregates partially or fully [7-8]. Its properties depend upon the characteristics, sizes, and content of EPS beads. Because of having very low density and hydrophobic nature of EPS beads, EPS concrete easily segregates and has poor bonding [4]. The introduction of EPS beads reduces workability [9]. The workability decreases steeply while increasing its content. The smaller size EPS beads give better strength. And, the increase in the EPS content decreases the densities and strength of concrete [4, 10-13]. Researchers tried to increase the bond and strengths of EPS concrete [4, 13].

Figure 1: Burning of wastage at open dumping site [16]

The commercial name of EPS is Thermocol. It is formed from a mixture of about 90-95 % polystyrene and 5-10 % gaseous blowing agent [14]. It is generally used as the packaging material and becomes waste after the packaged materials are in use. Due to its never decomposing characteristics, its wastage has given major problems in municipalities [14]. In Nepal, plastics and thermocol wastage make up 16 % of total urban waste [15]. The use of thermocol as waste in the landfill just increases its volume rapidly and the selection of the next landfill site makes the utmost difficult job. Moreover, the wastage in some open dumping sites in Nepal is regularly burned to minimize the volume of wastage (Fig.1).

The burn thermocol emits Chloro Fluro Carbon (CFCs) which is toxic and adversely affects the environment. After burning, it does not dissolve completely and leaves a molten residue. The residue when cooled, the residue gets hardened and emits pungent vapors [17]. With consideration of such existing environmental issues in Nepal, the author intended to extract the EPS beads from the thermocol to use in the concrete. It was learned that previous researchers used very few parameters on the percentages of EPS to evaluate the limited specific properties of strengths and durability. They just compared the EPS concrete with the control mixture they used but did not compare it with the commercially available other types of lightweight concrete. Thus, this paper describes the overall properties of EPS concrete in fresh and hardened states as well as the durability aspects. And, the comparison of EPS concrete was made with the commercially available auto-cleaved lightweight concrete (ALC) for the mechanical and durability properties [18].

2. Materials and Methods:

2.1. Properties of Materials and Mixture Proportions:

Ordinary Portland cement (Type I) was used in the experiment. Its specific gravity and Blaine value were measured following JIS R 5201 [19]. It was obtained at 3.15 and 4117 m^2/kg respectively. The chemical analysis of cement was done according to JIS R 5202 [20]. Table 1 summarizes the result of raw compounds and major compounds of the cement.

The maximum size, specific gravity, FM, and water absorption of the river sand were measured at 5.0 mm, 2.63, 2.81 and 1.84 % respectively [21-22]. Water was portable with a pH value of 7.0. The image of EPS beads extracted from thermocol is shown in Fig. 2 and their physical properties are summarized in Table 2.

The wastage of thermocol were collected from the nearby wastage collection center. The thermocol was crushed using to extract EPS beads.

Table 1: Compounds of Type I Portland Cement

Types	Content (%, by weight)
Lime (CaO)	63.8
Silica (SiO_2)	21.3
Alumina (Al_2O_3)	4.69
Iron Oxide (Fe_2O_3)	2.63
Sulfur trioxide (SO_3)	2.48
Others	4.09
Tri-calcium Silicate (C_3S)	55.5
Dicalcium Silicate (C_2S)	19.2
Tri-calcium Aluminate (C_3A)	7.98
Tetra-calcium aluminoferrite (C_4AF)	8.00
Others	9.29

The detail of the EPS concrete mixture proportion is shown in Table 3. Note that the EPS content was in percentage by total volume. It means the volume of base mortar decreased while increasing the percentage of EPS

Figure 2: EPS Beads Extracted from Thermocol Wastage

Table 2: Required Properties of EPS Beads

Particle size (mm)		Maximum compacted volume (%)	Void ratio (%)	Bulk Density (kg/m^3)	Specific Gravity
Minimum	Maximum				
1.20	2.50	60.60	39.40	21	0.035

Table 3: Mixture Proportion of EPS Concrete

Mix condition		Unit weight content (kg/m^3)						Theoretical density (kg/m^3)
W/C	EPS (%)	W	C	S	EPS	SP-8HS	VA	
0.30	0	360	1200	676	0.0	18.0	1.08	2240
	20	288	960	541	7.0	14.4	0.86	1800
	30	252	840	473	10.5	12.6	0.76	1580
	40	216	720	406	14.0	10.8	0.65	1360
	50	180	600	338	17.5	9.0	0.54	1140
	60	144	480	270	21.0	7.2	0.43	920

W: water; C: cement; S: sand; SP-8HS: superplasticizer; VA: viscosity agent

2.2. Mixing Procedures:

One batch of 30 L was mixed in a 50 L capacity double-shaft forced action mixer. The moisture content of sand was measured according to JIS A 1111 [23] and the unit water content of sand and water was adjusted. VA and SP were pre-mixed with cement and water respectively before mixing EPS concrete in the mixer. The batching of the ingredients required for one batch is shown in Fig. 3.

The cement (with VA) and sand were first mixed for 30 seconds. Then, the water (inclusion of SP-8HS) was added and mixed for 60 seconds.

Figure 3: Batching of Each Ingredient of EPS Concrete

After the mixing of the viscous mortar, EPS beads were charged into the running mixer part by part to avoid the overflowing of the beads. The charging of whole EPS beads was finished within 60 seconds. Finally, it was mixed for a further 180 seconds and EPS concrete was discharged from the mixer for different tests. The total mixing time was 5 minutes and 30 seconds.

2.3. Visual Observation, Workability, Test Specimens Preparation, and Tests:

After discharging the EPS concrete, the visual check was made to confirm that EPS concrete is well mixed concerning the distribution and coating condition of EPS beads inside the mortar. The visual condition of the sample of concrete after discharging is shown in Fig. 4. The figure shows that each EPS bead is uniformly distributed and well coated with mortar.

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Figure 4: Mixing condition of EPS concrete

The workability of EPS concrete was evaluated with the slump test following JIS A 1101 method [24]. Before making the test specimens, one panel with size of 500 mm (length)×500 mm (width)×50 mm (depth) was casted to check if the produced EPS concrete with different content of EPS can be casted with no difficult. The casting condition of the panel is shown in Fig. 5.

Figure 5: Casting Condition of EPS Panel

Ten numbers of cylinder specimens of ϕ50 mm×100 mm sizes were cast to check the 7-day and 28-day compressive strength of the specimen from each batch. The same number of cylinders were prepared for the splitting tensile tests. Ten numbers beam specimens of 400 mm × 100 mm × 50 mm (length × width × depth) were prepared for 7-day and 28-day flexural strength tests. Nine beam specimens of 10 cm×10 cm×40 cm were prepared for shrinkage, freeze and thawing, and water absorption tests (3 specimens for each test). Test items, specimen sizes (numbers), and test methods are summarized in Table 4.

The specimens were air cured for 24 hours with coverage of wet cloths. After 24 hours, the demolding of specimens was done carefully and they were put into water for wet curing until the test day. For each mixture proportions of EPS concrete, mixing of three consecutive batches was done and respective tests were conducted to assure the reappearance of the different properties of EPS concrete. It means the total number of 30 cubes for the 7-day and 28-day compressive strength test, 30 cubes for the 7-day and 28-day splitting tensile strength test, 30 beam specimens for the 7-day and 28-day flexural strength test, 9 beam specimens for shrinkage test, 9 beam specimens for freezing and thawing test, and 9 beam specimens for water absorption test were prepared. Most of the tests were conducted with the methods prescribed by Japan Industrial Standard. ASTM method was used for the freezing and thawing tests.

Table 4: Test Methods

Test Items	Test Specimens	Test Method
Compressive strength	ϕ5 cm×10 cm (10)	JIS A 1108 [25]
Splitting tensile strength	ϕ5 cm×10 cm (10)	JIS A 1113 [26]
Flexural strength	4 cm×4 cm×16 cm (10)	JISA1106 [27]
Shrinkage test	10 cm×10 cm×40 cm (3)	JIS A 1129 [28]
Freeze and thawing test	10 cm×10 cm×40 cm (3)	ASTM C 671-77 [29]
Water absorption test	10 cm×10 cm×40 cm (3)	JIS A 1404 [30]

The experiment method for the water absorption is shown in Fig. 6. Air dry beam specimens (10 cm × 10 cm × 40 cm) were dipped into 3 cm depth water and water absorption was measured. The water absorption tests of ALC specimens were also conducted for comparison.

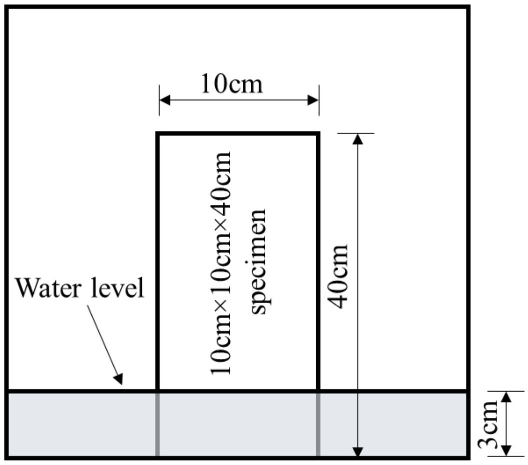

Figure 6: Experiment Method for Water Absorption Test

3. Results and Discussions:

In the visual check, each mix was well mixed and no segregation was noticed. It was due to the use of both superplasticizers and viscosity agents. EPS beads were uniformly distributed and well coated with the mortar. However, EPS concrete with 60 % EPS had very less free mortar. It was because 60 % was the optimum content of EPS with the consideration of the maximum compacted volume of EPS (60.6 %). The upper surfaces of panels with 0 % EPS beads and 60 % EPS beads are shown in Fig. 7. Figure shows that the upper surface of EPS concrete cannot be smooth as that of base concrete. However, it is argued that such surface of the panel gives the aesthetic show while using as panels in the wall.

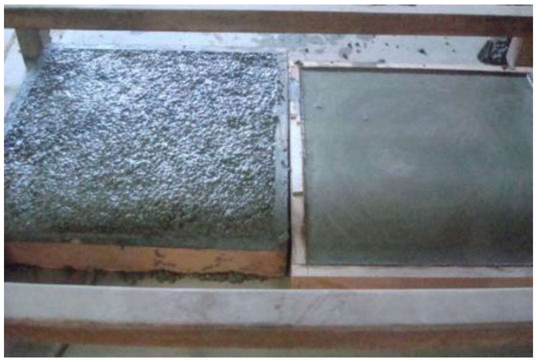

Figure 7: Upper Finishing Surface of Base Concrete and EPS Concrete with 60% EPS Beads

3.1. Workability:

The data of the slump test is given in Table 5. The inclusion of EPS beads drastically decreases the workability from that of the control mixture and goes on decreasing while increasing its content [10, 31]. The use of the EPS also significantly decreased the slump value from that of the control mixture in this work. EPS concrete with an EPS content of up to 40 % was well workable and easier for casting the specimens. However, EPS concrete of 50 % and 60 % were found less workable, but there was no problem with casting. It was due to the use of SP. The average values of EPS concrete with ranging content of EPS are listed in Table 4. The average values are of 3 batches for the same content of EPS. The data show that the slump significantly decreased while increasing the content of EPS.

The slump values were decreased by 52%, 67%, 83 %, 94 %, and 98 % for 20, 30, 40, 50, and 60 percentages of EPS respectively.

Table 5: Slump Values of EPS Concrete

EPS (%)	**0**	**20**	**30**	**40**	**50**	**60**
Slump (cm)	24.5	11.7	8.0	4.3	1.6	0.50

Table 6: Average Density of EPS Concrete with the Standard Deviation

EPS (%)		**0**	**20**	**30**	**40**	**50**	**60**
Density (Kg/m3)	7-day	2246	1742	1553	1359	1106	889
	28-day	2250	1756	1568	1371	1120	889

Table 6 shows the average values of 7-day and 28-day hardened densities of EPS concrete with ranging volume percentages of EPS beads. The data of one average value was 15 data (5 specimens ×3 batch). The 28-day density of EPS concrete was a little bit higher than those of 7-

day. The decrease in density of EPS concrete from that of the control mixture was by about 21 %, 29 %, 38 %, 48 %, and 57 % for the EPS content of 20 %, 30 %, 40 %, 50 %, and 60 % respectively. The standard deviation was ranging from the minimum value of 4.3 kg/m^3 to the maximum value of 19.3 kg/m^3 satisfying the quality control of the experiment. It was a 17, 26, and 33 % decrease in EPS concrete with 20 %, 30 %, and 40 % respectively in the study of Nikbin and Golshekan [32]. They used the control mixture of the base concrete with the use of coarse aggregate, but this study used only the base mortar without coarse aggregate. It revealed that the effect of EPS beads on the decrease of the density is more in the base mortar than in the base concrete.

While introducing 20 % of EPS beads in the control mixture, the density of EPS concrete decreased down to 1762 kg/m^3 and it fell into the category of lightweight concrete (≤ 1800 kg/m^3). Babu et al. obtained lightweight concrete (about 1790 kg/m^3) by introducing 30 % EPS beads to the control mixture containing coarse aggregate [13]. It is because the density of their control mixture (2410 kg/m^3) was more than the control mixture in this study (about 2240 kg/m^3). It means the density of EPS concrete not only depends upon the percentage of EPS but also on the density of the control mixture. Considering the effect of the density of the control mixture and the EPS content, the empirical model was developed based on the EPS content (in percentage) and the theoretical density of the control mixture. It is given in Eq. 1.

$$\rho_{EPS} = \left(1 - \frac{EPS}{100}\right)\rho_c \qquad (1)$$

In the equation, ρEPS = density of EPS concrete, EPS = percentage of EPS, ρ_c = theoretical density of the control mixture. It is clear from the given figure that the empirical model well matches all experimental data of this study. Thus, the density of the EPS concrete, for the different percentages of EPS, can be estimated with the given mixture proportion of the control mixture. The density of EPS concrete with 60 % content of EPS was also higher than that of ALC [18].

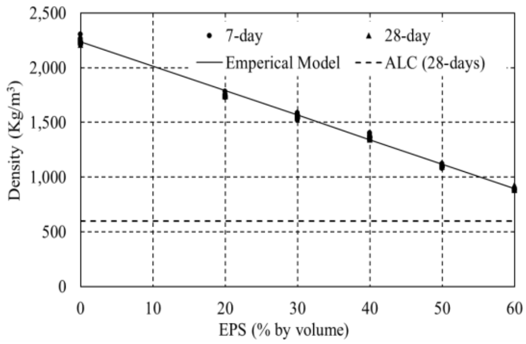

Figure 8: Densities of EPS Concrete with Different Content of EPS

3.2. Compressive Strength:

The average values of the compressive strength test are summarized in Table 7. The average value consists of 15 test data. The standard deviation of each average value was in the range of 0.13 MPa - 1.54 MPa.

Table 7: Average Values of Compressive Strength Tests of EPS Concrete

EPS (%)		0	20	30	40	50	60
Compressive strength (MPa)	7-day	39.2	14.5	11.1	8.70	5.78	2.88
	28-day	59.9	22.6	16.9	11.5	7.23	4.06

The decrease of 28-day compressive strength was 62 %, 72 %, 81 %, 88 %, and 93 % respectively. The introduction of EPS in the control mixture drastically decreased the compressive strength and went on decreasing while increasing the content of EPS.

All experimental data were plotted and the trend of each curve was studied (Fig. 9). One set of data in each percentage of EPS contains 15 data. The trend of the decrease was exponential while introducing and increasing the EPS content. The simple empirical model was developed as given in Eq. 2.

$$f_{cEPS} = f_c e^{-0.041EPS} \qquad (2)$$

Here, f_{cEPS} = compressive strength of EPS concrete. f_c = compressive strength of the control mixture which can be estimated with other established models. In this study, experimental data of the control mixture was used. EPS =

percentage of EPS by volume of the total mixture. The experimental data of the compressive strength of the control mixture was used. The curves developed from this model were also plotted for comparison.

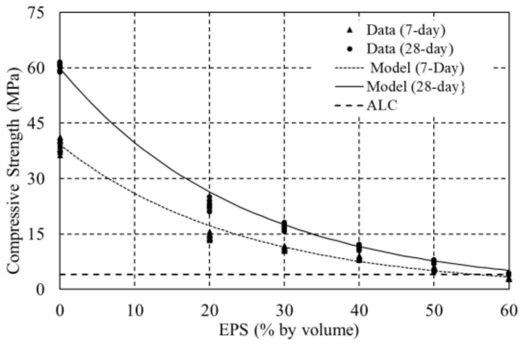

Figure 9: Compressive Strength of EPS Concrete with Different Content of EPS

The analytical curve almost matches the experimental data. It was also verified from this series of experiments that the 28-day compressive strength of EPS concrete satisfied the minimum requirement of the ALC (4.0 MPa), to be used in the non-structural elements like in-fill and partition walls.

3.3. Young's Modulus:

The average values of Young's moduli, determined from the 28-day compressive strength tests, of EPS concrete are summarized in Table 8. The standard deviations were in the range of 223 MPa-960 MPa. The decrease of Young's moduli was 45 %, 56 %, 61 %, 70 %, and 77 % for the EPS content of 20 %, 30 %, 40 %, 50 %, and 60 % respectively. Young's modulus obtained by Xu et al. [33] obtained Young's modulus of 3600 MPa with *W/C*=0.45 and EPS content of 40%, which was less than this study (7147 MPa), It was because their control mixture was concrete and 28-day compressive strength was only 1.9 MPa (11.5 MPa in this study). Young's modulus depends upon the compressive strength.

All data of Young's moduli plotted against the percentage of EPS is shown in Fig. 10. The trend of decrease was quite similar to that of the compressive strength. Eq. 3 gives the empirical model.

$$E_{EPS} = E_c e^{-0.025EPS} \quad (3)$$

Here, E_c = Young's modulus of the control mixture. E_{EPS} = Young's modulus of EPS concrete respectively. EPS = percentages of EPS. The figure itself clarifies that the experimental data matches the empirical model. Young's modulus of EPS concrete is larger than that required in ALC (2000 MPa).

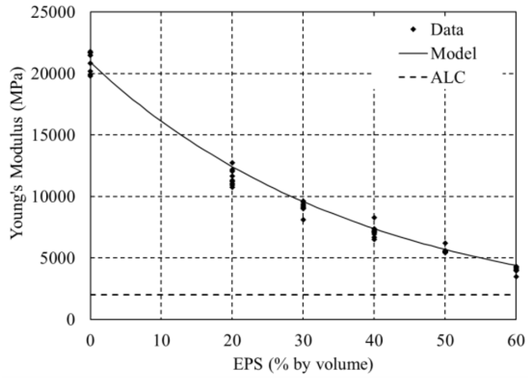

Figure 10:Young's Modulus of EPS Concrete

3.4. Flexural Strength:

The average values of flexural strength tests are summarized in Table 9. The standard deviation was from 0.06 MPa to 0.11 MPa. The decrease of the flexural strength from the control mixture was 26 %, 41 %, 51 %, 57 %, and 69 % for the EPS content of 20 %, 30 %, 40 %, 50 %, and 60 % respectively.

While increasing the content of EPS, both 7-day and 28-day flexural strengths decreased linearly in the form of the equation $f_{bEPS} = f_{bc} - mEPS$ with $R^2 \geq 0.98$. Here, f_{bEPS} is the flexural strength of concrete. f_{bc} is the flexural strength of EPS concrete. EPS is the percentage of EPS. m is the constant depending upon the content, sizes, and gradation of EPS. R^2 is the coefficient of determination. Both 7-day and 28-day flexural strengths of EPS concrete were higher than that required in ALC (1.0 MPa). No previous data were available for comparison since most of the researchers carried out only the splitting tensile test to evaluate the tensile strength of concrete.

Table 8: Young's Modulus of EPS Concrete

EPS (%)	0	20	30	40	50	60
Young's modulus (MPa)	20898	11540	9134	7147	5576	4047

Table 9: Average flexural strength EPS Concrete

EPS (%)		0	20	30	40	50	60
Flexural strength (MPa)	7-day	4.41	3.50	2.82	2.26	1.94	1.59
	28-day	5.21	3.86	3.08	2.54	2.24	1.61

Table 10: Average Values of Splitting Tensile Strength Tests

EPS (%)		0	20	30	40	50	60
Splitting tensile strength (MPa)	7-day	3.44	1.79	1.36	0.94	0.62	0.41
	28-day	4.43	2.40	1.77	1.31	0.87	0.55

3.5. Splitting Tensile Strength:

The average values of splitting tensile strength test results are summarized in Table 10. The standard deviation was between 0.02 MPa-0.15 MPa. The decrease of the splitting tensile strength from the control mixture was 46 %, 60 %, 70 %, 80 %, and 88 % for the EPS content of 20 %, 30 %, 40 %, 50 %, and 60 %.The trend of decrease was quite similar to that of the flexural strength. The splitting tensile strength obtained by Xu et al [33], with *W/C* = 0.45 and 40 % EPS content, was also smaller (0.6 MPa) than in this study (1.31 MPa). The reason behind it is already explained in the case of Young's modulus.

3.6. Drying Shrinkage:

Shrinkage is the reduction in the volume of freshly hardened concrete exposed to ambient temperature and humidity. Drying shrinkage is due to loss of water by evaporation from fleshly hardened concrete exposed to the air [34]. It is mainly due to the water loss in C-S-H and internal moisture changes during the hydration process [35].

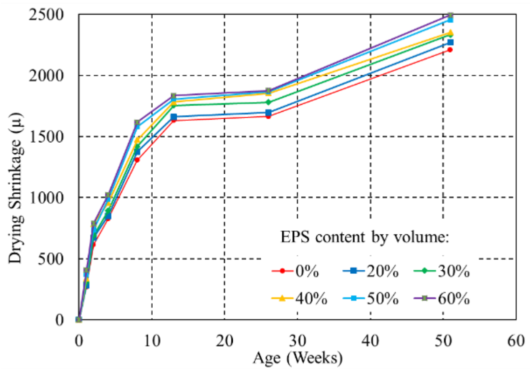

Figure 11: Drying Shrinkage of EPS Concrete

The drying shrinkage values of EPS concrete using different percentages of EPS at different ages is shown in Fig. 11. The values were steeply increased up to 7 days and then the increment was gradual. However, no difference was noticed between 7 days and 28 days, then increased gradually at 51 days. It was noticed that the increase of the percentage of EPS slightly increases the drying shrinkage value. The values obtained at 51 days were 2210 µ, 2270 µ, 2332 µ, 2352 µ, 2455 µ, and 2493 µ for 0 %, 20 %, 30 %, 40 %, 50 %, and 60 % EPS respectively. The obtained result agreed with the work of Maghfouri et al. that EPS concrete has larger drying shrinkage than ordinary concrete and increases with the increment of EPS [36]. The drying shrinkage increased with the increase of the EPS content. Because EPS beads have deformation characteristics under shrinkage.

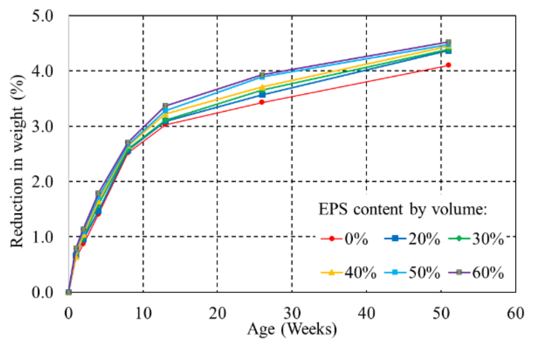

Figure 12: Weight Reduction of EPS concrete in Drying Shrinkage Test

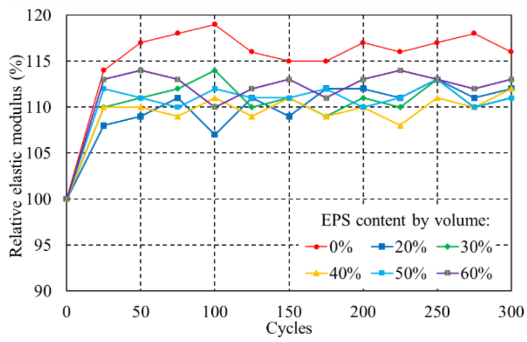

Figure 13: Relative Modulus of EPS Concrete in Different Cycles

The reduction of weight in EPS concrete due to drying shrinkage is shown in Fig. 12. The reduction of weight was least in the EPS concrete with 0 % EPS (4.1 %) and highest in 60 % EPS (4.52 %). However, the difference was very small and thus can be said that the EPS content has a negligible effect on weight reduction in drying shrinkage. The drying test verifies that the addition of EPS in mortar/concrete does not deteriorate durability.

3.7. Freezing and Thawing:

The relative modulus of EPS concrete while increasing the cycles in freezing and thawing tests is shown in Fig. 13. It is known from the result that the relative elastic modulus of EPS concrete did not decrease even after 300 cycles. From Fig. 14, it was also understood that freezing and thawing have less influence on the weight of EPS concrete. Freezing and thawing test results also show that the EPS concrete has the same level of durability as that of ordinary mortar/concrete. Yuan et al. [37] have claimed that the frost resistance of EPS concrete is weaker than that of ordinary concrete. However, such a large difference was not noticed in this study.

3.8. Water Absorption:

Water absorption test results are summarized in Table 11. Each data consists of the average of the test data of three specimens with a negligible variation. Despite the different content of EPS, the water absorption of EPS concrete was in between 2.18 %-2.36 %. The results showed that there is no effect of EPS on the water absorption behavior of EPS concrete. However, the water absorption of ALC was significantly higher (46.8 %). EPS concrete is better than ALC for the durability aspect concerning the water absorption behavior. Herki [38] reported that higher water absorption was obtained in the higher content of EPS. He forwarded the reason for poor compaction and entering of water through the channel of voids. However, Babu et al. [13] reported less absorption in EPS concrete which agrees with the result obtained in this study. Vejelis and Vaitkus [39] also reported the advantages of using EPS due to having lesser water absorption. Sufficient superplasticizers and viscosity agents should be added to avoid the voids due to poor compaction of EPS concrete.

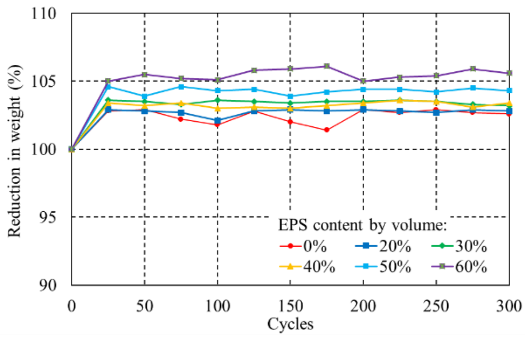

Figure 14: Weight Reduction of EPS Concrete in Freezing and Thawing Test

Table 11: Water Absorption of ALC Mortar and EPS Con After 72 hours

EPS (%)	0	20	30	40	50	60	ALC
Water absorption (% by wt.)	2.36	2.33	2.28	2.25	2.22	2.19	46.8

4. Conclusions:

The following conclusive points were drawn from this research work.

- The inclusion of EPS in mortar/concrete drastically decreases the workability, density, compressive strength, flexural strength, splitting tensile strength, and Young's modulus.
- The decrease of 28-day compressive strength from that of the control mixture was by 62 %, 72 %, 81 %, 88 %, and 93 % for the EPS concrete with 20 %, 30 %, 40 %, 50 %, and 60% respectively. It was 45 %, 56 %, 61 %, 70 %, and 77 % decrease for the Young's modulus, 26 %, 41 %, 51 %, 57 %, and 69 % for the flexural strength and 46 %, 60 %, 70 %, 80 %, and 88 % for the splitting tensile strength respectively.
- It is possible to use up to 30 % of EPS content to produce the structural EPS concrete. With the increase of the content beyond 30 %, non-structural EPS concrete can be produced. However, the optimum content of EPS is 60 %.
- All strengths and Young's modulus increase with the increment in the density of EPS concrete.

- It was verified from both drying shrinkage and freezing and thawing tests that the EPS does not affect durability.
- Assurance of reappearance on all properties of EPS concrete was confirmed by attaining the less standard deviation from all tests of 3 consecutive same batches.
- EPS concrete has a similar water absorption capacity to that of normal concrete which is one of the major benefits to the ALC for durability aspect.
- The developed empirical models well satisfied the experimental data.

In general conclusion, the thermocol never should be treated as waste and burned or filled in damping site; but should be used in concrete to protect the environment.

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